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CONTRACTOR REPORT ARLCD-CR-85002

PRODUCT IMPROVEMENT PROGRAM FOR THE M577 FUZE--VOLUME 2, REDESIGNED ESCAPE WHEEL AND LEVER

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U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
LARGE CALIBER WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this contract was to redesign the timer escape wheel and lever to make more efficient use of the input torque and to provide a locking feature for the timer spin detent after it spins out. This redesign reduced the undesirable effects of balloting during ballistics by eliminating mechanical interference in the escapement. Ballistic test results with the redesigned escape wheel and lever were excellent. The redesign of the timer spin detent system was dropped because a ballistic test program that could determine whether the redesigned spin detent solves the balloting program could not be found.

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CONTENTS

TABLES

INTRODUCTION

The objective of this contract was to reduce the cost of the fuze, enhance the producibility, and reduce the susceptibility of the fuze to severe weapon environment by redesigning the following:

1. the timer escape wheel and lever to make more efficient use of the input torque;

2. the timer mainspring to achieve a torque curve with a smaller slope;

3. the timer spin detent to provide a locking feature for the detent after it spins out.

This redesign strived to reduce the undesirable effects of balloting during ballistics in certain weapons by eliminating mechanical interference in the escapement.

The functional parameters used in the development were ballistic environments of 30,000 g's setback and 30,000 RPM spin and a temperature environment from -35 degrees to 145 degrees Fahrenheit.

Because of another product improvement program contract granted to Bulova Systems and Instruments Corporation to pursue a redesign of the timer mainspring, the portion of this contract dealing with the mainspring was never pursued.

TECHNICAL DISCUSSION

Redesigned Escape Wheel and Lever

Hamilton Technology, Inc. began its work for this contract with the design of a timer escape wheel and lever developed by Westclox Military Products. The newly designed Westclox escapement looks different from the present escapement. The Westclox lever is symmetrical and embraces 3½ teeth, as opposed to the present lever which embraces 4½ teeth. The escape wheel has shorter and stubbier teeth with large fillets, which provides for easier manufacturing.

Because of these changes, this escapement operates slightly differently than the current escapement. In the current design, the balance impulse pin is trapped in the slot of the lever after the lift portion of the cycle is completed. The impulse pin must push the lever out of its path to continue moving in that direction. The energy required to move the lever comes from the balance wheel. With the Westclox escapement, because of the geometry, the impulse pin is free to move after lift has been completed. The Westclox escapement is more energy efficient than the current escapement; therefore, we expect it to achieve a higher average amplitude.

A second advantage to the Westclox escapement is its increased drop clearance. Drop is the distance between the one pallet pin and the escape wheel tooth when the second pallet pin first contacts the escape wheel (see figure 1). The present escapement provides approximately .0045 inches clearance to the receiving pallet pin, but only .0014 inches of clearance to the exit pallet pin. The Westclox escapement provides about .005 inches of clearance to both pins. This additional clearance provides greater manufacturing latitude.

The Westclox escape wheel incorporates a more durable tooth design. Each tooth is shorter, and the tooth width is much wider because the fillet on the backside of the tooth is made to conform to the actual clearance requirements of the lever pallet pin. This allowed the radius of the fillet to be increased from .006" to .032". This larger radius not only improves the manufacturability but also provides a better distribution of oil. The larger radius prohibits the oil from being trapped behind the tooth as happens in the current design.

The changes to the lever also offer some advantages. The Westclox lever is symmetrical and lighter. Therefore, the entrance and exit pins produce amplitudes of a more equal magnitude than the present unsymmetrical lever.

Several minor changes were made to the design by Hamilton. Westclox had recommended a change to the impulse pin radius to improve manufacturability; Hamilton decided to retain the present radius because of a possible rubbing with the suggested radius. After the first ballistic test, the lever configuration was slightly changed. Several radii on the lever horn and passing hollow were changed to ease the transfer of the impulse pin from one locking surface of the lever to the other under worst case conditions.

Initial ballistic testing of thirty fuzes was performed with levers and escape wheels that were both made using the wire electrical discharge machining process. The fuzes were fired in high and low zone weapons with excellent results. The timers used in this test had an average amplitude of 151^{o}, which is about 20% better than production timers being built at the same time.

Changes to several radii of the lever described earlier were made after the initial ballistic test. Another group of thirty fuzes, incorporated these changes to the lever and used hobbed escape wheels, were built for ballistic testing. Again, the ballistic results were good. However, this time the timers did not exhibit unusually high amplitudes; the amplitudes were only slightly higher than those achieved at the time by production timers.

Based on the results of this test, it was decided to order a compound die to manufacture the lever. The final ballistic test and all ballistic tests, combined with the timer redesign, were performed with stamped levers. Ballistic test results, with the stamped levers, were excellent.

No major problems occurred in the manufacturing of the lever and escape wheel when the final processes were used. Staking the pallet pins and meeting the true position tolerance was extremely difficult. Several staking fixtures were designed, built, and tested. The final design of the staking fixture produced lever assemblies with a yield of 80% relative to true position of the pallet pins which is significantly lower than the production yield. These lever assemblies were inspected using a comparator chart which is more critical than the functional gage used in production. This yield is expected to increase when a functional gage is used.

The redesigned lever and escape wheel were ballistically tested in combination with the timer redesign, developed under Task 3 of Contract DAAK10-79-C-0169, to determine if the two changes would be compatible. The results of these tests were excellent.

Setback Locked Spin Detent

The present timer spin detent is biased toward the center of the fuze by a light spring. Before the fuze experiences setback and spin, the spin detent serves as a detent for the balance wheel. After the spin detent is released by the setback pin, the spin detent spins out and is held clear of the balance wheel by centrifugal force. A sudden side load, known as balloting, can force the detent against the balance wheel. This may stop the balance wheel and result in a dud. This phenomenom occurs in some of the weapons in which the M577 fuze is used.

Several devices that would lock the spin detent in its spun out position were investigated. The device decided upon is a modification of the design presented in the proposal for this contract. In this design, the timer spin detent system is essentially the same as the present one, with the addition of one feature. This feature is a cavity in plate no. 2, which will capture the spin detent after it spins out. As shown in figure 2, the cavity in plate no. 2 is configured so that the spin detent, having been moved outward by spin, is forced into this cavity by setback. The cavity then constrains the spin detent, preventing it from being moved inward by balloting forces, as long as setback persists. Material was removed from the spin detent in the area around the pivot hole so the detent can fall into the cavity of plate no. 2. The slot in plate no. 3 was elongated to accommodate the projection of the spin detent.

A small quantity of parts were modified and assembled into timers for laboratory testing. After testing, it was decided the pivot hole in the spin detent should be enlarged to prevent the spin detent from hanging up on the pivot when sliding down. Laboratory testing indicated this design has merit and is workable. However, a ballistic test program that could determine whether the redesigned spin detent solves the balloting problem could not be found. Consequently, this phase of the program was dropped.

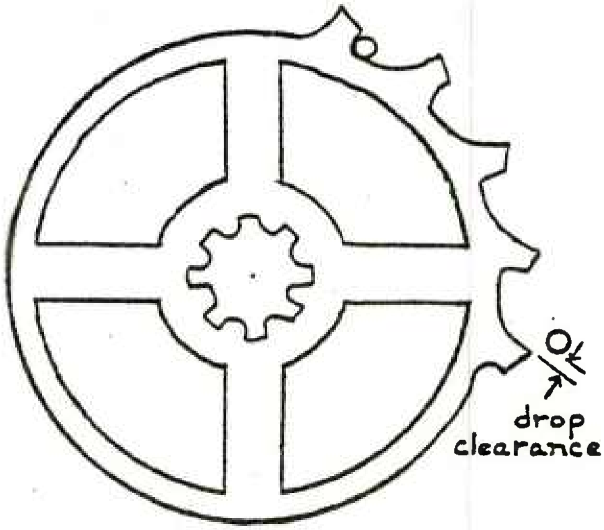

Figure 1 Pallet pin and escape wheel clearance

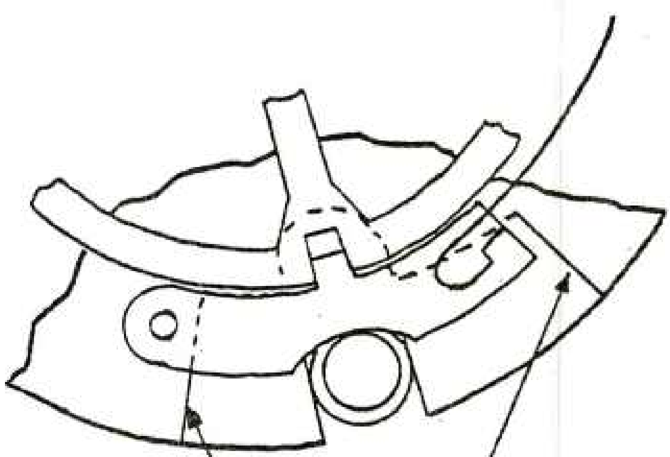

Figure 2 Spin detent system

TESTING

Spin Test

Ten units with the redesigned escape wheel and lever were tested in concentric and .030" eccentric spin at speeds up to 30,000 RPM in May 1983. The beat rate was measured and recorded at various speeds; however, the amplitude was not recorded because of equipment problems. The beat rate was consistent in most units until 28,000 RPM. Then, the timers began to slow down and some of them stopped. Unit by unit results are shown in table 1.

Air Gun Test

Ten units, with the redesigned escape wheel and lever, were built and air gun tested in combination with the trigger assembly combined safety plate redesign. One unit was destroyed due to a malfunction of the air gun. All other timers operated for at least 100 seconds after the test, including the ones exposed to 30,000 g's. Beat rate and amplitude data for each unit are given in table 2.

Jolt and Jumble Test

Six fuzes, with the redesigned escape wheel and lever, were built and tested per MIL-STD-331, Test 102.1 and 101.2. Units were examined and found to be safe to handle and dispose of after testing.

Ballistic Test I

Thirty fuzes, with the Westclox designed escapement and thirty control fuzes were shipped to Yuma Proving Grounds and ballistically tested in September 1982. Both the levers and escape wheels were made using the wire electrical discharge machining process. Both the reliability and timing accuracy were excellent. A summary of the results is given in table 3.

Ballistic Test II

Thirty test fuzes and thirty control fuzes were shipped to Yuma Proving Grounds and ballistically tested. The test fuzes incorporated the lever modification described in the technical discussion, and the escape wheels were hobbed as opposed to the electrical discharge machined escape wheels used in the first test. A summary of the results is given in table 4.

Transportation Vibration Test

Twenty fuzes, with the final design of the escape wheel and lever, were tested per MIL-STD-331, Test 104, Procedure 2. These units were X-rayed after the test and found to be safe to handle. They were shipped to Yuma Proving Grounds and ballistically tested. The results are shown in table 5.

Table 1. Spin test results

Unit	Before Test Beat Rate	Before Test Amplitude	After Test Beat Rate	After Test Amplitude	Max. Operatin RPM Concentric	Max. Operatin RPM Eccentric
1	80.70	132	Broken hairspring		30,000	29,700
2	80.76	128	80.58	134	28,000	28,000
3	80.72	128	80.63	128	26,000	28,000
4	80.70	132	80.58	136	28,000	30,000
5	80.76	134	80.60	128	30,000	28,000
7	80.68	128	Broken hairspring		28,000	29,700
8	80.77	128	80.60	128	30,000	26,000
9	80.72	132	80.58	136	26,000	28,000
10	80.66	130	Broken hairspring		32,000	26,000
12	80.69	128	80.60	136	21,500	26,000

Table 2. Air gun results

Unit	g Level	Before Beat Rate	Before Amplitude	After Beat Rate	After Amplitude
1	31991	80.67	118	80.86	72
2	31283	80.69	118	80.49	120
3	33406	80.70	120	80.49	118
4	25982	80.68	120	80.71	104
5	29234	80.75	118	80.63	114
6	28371	80.77	116	80.82	96
7	30481	80.70	116	80.82	106
8	30100	80.80	118	80.78	72
9	31231	80.69	124	80.58	120
10	30492	80.70	126	Destroyed in Air Gun	

Table 3. Ballistic test I results

Weapon	Zone	Environ-ment (°F)	Time	Funct.	Mean	Std. Dev.
Test Units						
155mm, 198 system	8 (M203)	70	105.0	20/20	104.972	0.259
8 in., M2A1	1	-35	25.0	10/10	24.955	0.072
Control Units						
155mm, 198 system	8 (M203)	70	105.0	20/20	105.220	0.237
8 in., M2A1	1	-35	25.0	9/10	24.950	0.064

Sequential Rough Handling Test

A modified sequential rough handling test was performed on sixteen fuzes with the final version of the redesigned lever and escape wheel. A flow chart of the test plan is shown in figure 3. All units were X-rayed and inspected after the seven foot packaged and five foot unpackaged drops at -50°F and 145°F and then subjected to ballistic testing. The X rays revealed three units had timer setback pins down after the five foot drop test. Eleven of fifteen fuzes functioned properly when ballistically tested. One was considered a no test because the fuze was set on the shipping setting when fired. None of the duds was recovered, but three of them were expected because of the timer setback pin. Ballistic data are shown in table 5.

Ballistic Test III

Fuzes, with the final version of the redesigned lever and escape wheel, were built and ballistically tested at Yuma Proving Grounds in September 1983. The reliability of the fuzes was 100%; means and standard deviations were excellent. A summary of the results is given in table 5.

Preliminary Combination Ballistic Test

A preliminary ballistic test, with the redesigned lever and escape wheel combined with the timer redesign, was performed in December 1983 as part of a diagnostic test on the timer redesign. Test results, as shown in table 6, were acceptable.

Combination Ballistic Test

The following groups of 150 fuzes were ballistically tested at Yuma Proving Grounds in March 1984:

1. Standard timer with a redesigned escape wheel and lever.

2. Redesigned timer with a redesigned escape wheel and lever.

3. Control.

Test results were good; however, some duds did occur with the redesigned escape wheel and lever. The reliability was 98.7% for group 1, 97.9% for group 2, and 96.2% for group 3. A summary of the test results is given in table 7.

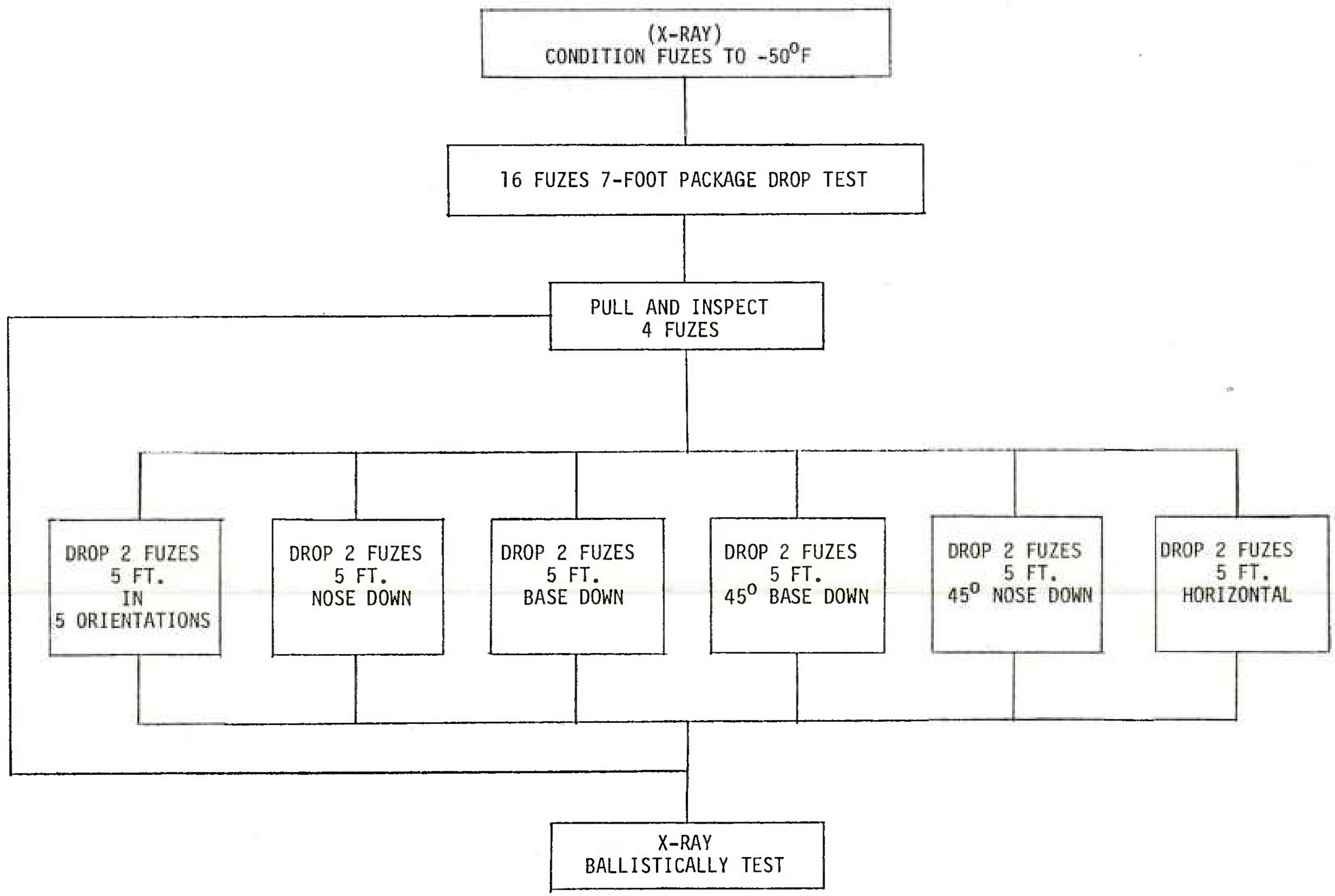

Figure 3. Sequential rough handling best flow chart

Table 4. Ballistic test II results

Test Units

Weapon	Zone	Environ-ment (°F)	Time	Funct.	Mean	Std. Dev.
155mm, M185, M107	8	70	75.0	10/10	75.045	0.116
155mm, M185, M483	8	70	75.0	9/10	75.20*	0.12

Control Units

Weapon	Zone	Environ-ment (°F)	Time	Funct.	Mean	Std. Dev.
155mm, M185, M107	8	70	75.0	10/10	75.087	0.167
155mm, M185, M483	8	70	75.0	10/10	75.30*	0.07

* Stop watch times.

Table 5. Ballistic test III results

Test Units

Weapon	Zone	Environ-ment (°F)	Time	Funct.	Mean	Std. Dev.
155mm, M185, M107	8	70 TV	75.0	10/10	50.032	.118
155mm, M185, M107	8	70	75.0	10/10	75.027	.123
155mm, M185, M483	3	70	25.0(FFE)	10/10	25.30[1]	.173
155mm, M185, M483	8	70	80.0(FFE)	10/10	80.145[1]	.082
155mm, M198 system	8 (M203)	70	105.0	10/10	104.990	.348
155mm, M549, RAP	8 (M203)	70	50.0	20/20	50.084[2]	.087
105mm, M103	7	145	50.0	10/10	50.151	.052
105mm, M103	7	70	50.0	10/10	50.081	.083
105mm, 204 system	8	145	75.0	10/10	75.092	.173
8 in., M2A1	1	-35	25.0	10/10	24.859	.048
8 in., M2A1	1	70	15.0	10/10	14.991	.074
8 in., M201A1	9	70	105.0	10/10	105.148	.115

Control Units

Weapon	Zone	Environ-ment (°F)	Time	Funct.	Mean	Std. Dev.
155mm, M185, M107	8	70 TV	50.0	9/10	50.031	.096
155mm, M185, M107	8	70	75.0	10/10	75.084	.142
155mm, M185, M483	8	70	80.0(FFE)	10/10	80.351	.103
155mm, 198 system	8 (M203)	70	105.0	10/10	105.237	.124
155mm, M549, RAP	8 (M203)	70	50.0	10/10	50.069	.120
105mm, M103	7	145	50.0	10/10	50.121	.098
105mm, 204 system	8	145	75.0	10/10	75.089	.245
8 in., M2A1	1	-35	25.0	10/10	24.914	.077
8 in., M201A1	9	70	105.0	10/10	105.086	.161

1. Based on stop watch times.

2. Outlier removed.

Table 6. Preliminary combination ballistic test result

Weapon	Zone	Environment (°F)	Time	Funct.	Mean	Std. Dev.
155mm, M198 system	8 (M203)	-50	105.0	10/10	104.840	0.335

Table 7. Combination ballistic test results

TPR 2858, Supplement 12

Lot# HAT84B000E131 - Test Units with Timer Redesign and Modified Escapement

Weapon	Zone	Environment (°F)	Time	Funct.	Mean	Std. Dev.	LPD
155mm, M185 (M804)	8 (M119)	70	75.0	10/10	75.053	.134	0
155mm, M185 (M804)	8 (M119)	70 TV	50.0	10/10	50.025	.115	0
155mm, M185 (M483)	8 (M119)	-40	80.0(FFE)	10/10	79.985	.062	-
155mm, M185 (M483)	8 (M119)	145	83.0(SR)	13/13	83.159	.128	-
155mm, M199 (M549)	8 (M203)	-50	50.0	10/10	49.902	.063	-
155mm, M199 (M549)	8 (M203)	+145	50.0	10/10	50.058	.066	-
105mm, M103	7	145	50.0	7/10[2]	50.094	.082	0
105mm, M103	7	70	50.0	10/10	50.059	.045	0
105mm, M102 (W/Muz. brk)	8 (XM200)	145	75.0	10/10	75.164	.198	0
8 in., M2A1(XM844)	1	-35	25.0	10/10	25.000	.060	0
8 in., M2A1(XM844)	1	+70	15.0	10/10	15.096	.041	0
8 in., M201A1(XM844)	1	-35	25.0	10/10	25.017	.055	0
8 in., M201A1	9	-50	100.0	10/10	99.841	.076	-
8 in., M201A1	9	+145	100.0	12/12	100.091	.068	-

Lot# HAT84B000E132 - Test Units with Standard Timer and Modified Escapement

Weapon	Zone	Environment (°F)	Time	Funct.	Mean	Std. Dev.	LPD
155mm, M185 (M804)	8 (M119)	70	75.0	10/10	75.058	.157	0
155mm, M185 (M804)	8 (M119)	70 TV	50.0	10/10	50.057	.073	0
155mm, M185 (M483)	8 (M119)	-40	80.0(FFE)	8/10[1]	79.865	.115	0
155mm, M185 (M483)	8 (M119)	145	83.0(SR)	10/10	83.134	.127	-
155mm, M199 (M549)	8 (M203)	-50	50.0	10/10	49.958	.087	-
155mm, M199 (M549)	8 (M203)	145	50.0	10/10	50.083	.066	-
155mm, M199 (M101)	8 (M203)	-50	105.0	10/10	104.843	.227	-
105mm, M103	7	145	50.0	10/10	50.118	.084	0
105mm, M103	7	70	50.0	10/10	50.020	.038	0
105mm, M102 (W/Muz. brk)	8 (XM200)	145	75.0	10/10	75.095	.242	-
8 in., M2A1 (XM844)	1	-35	25.0	10/10	24.977	.106	0
8 in., M2A1 (XM844)	1	70	15.0	10/10	14.966	.088	0
8 in., M201A1(XM844)	1	-35	25.0	10/10	24.926	.067	0
8 in., M201A1	9	-50	100.0	10/10	99.833	.085	-
8 in., M201A1	9	+145	100.0	10/10	100.193	.083	-

Table 7 (cont.)

Lot #HAT84B000E133 - Control Units

Weapon	Zone	Environ-ment (°F)	Time	Funct.	Mean	Std. Dev.	LPD
155mm, M185 (M804)	8 (M119)	70	75.0	10/10	75.129	.143	0
155mm, M185 (M804)	8 (M119)	70 TV	50.0	10/10	50.105	.105	0
155mm, M185 (M483)	8 (M119)	-40	80.0(FFE)	9/9	79.868	.165	-
155mm, M185 (M483)	8 (M119)	145	83.0(SR)	10/10	83.273	.042	-
155mm, M199 (M549)	8 (M203)	-50	50.0	10/10	49.903	.103	-
155mm, M199 (M549)	8 (M203)	145	50.0	10/10	50.204	.135	-
155mm, M199 (M101)	8 (M203)	-50	105.0	10/10	104.803	.420	-
105mm, M103	7	145	50.0	10/10	50.122	.099	0
105mm, M103	7	70	50.0	10/10	50.027	.096	0
105mm, M102 (W/Muz. brk)	8 (XM200)	145	75.0	20/20	75.249	.208	-
8 in., M2A1 (XM844)	1	-35	25.0	7/10[3]	24.951	.096	0
8 in., M2A1 (XM844)	1	70	15.0	10/10	15.071	.069	0
8 in., M201A (XM844)	1	-35	25.0	10/10	24.909	.047	0
8 in., M201A1	9	-50	100.0	8/10	99.760	.084	-
8 in., M201A1	9	145	100.0	9/10	100.300	.100	-

1. Cargo was expelled from round in both reported duds; it is assumed function occurred on ground impact.

2. Two duds recovered; analysis showed clock did not start. Third dud was FGI.

3. Two duds recovered; analysis on one showed timer ran, and trigger fired, but SSD did not arm. The other one was too damaged; only the SSD and part of trigger were recovered.

CONCLUSIONS AND RECOMMENDATIONS

Timers with the redesigned lever and escape wheel were subjected to the required laboratory and ballistic tests with excellent results. The proposed design was also ballistically tested with the timer redesign concept.

Hamilton Technology believes the escapement with the redesigned escape wheel and lever is a feasible replacement to the current escapement. However, before this design is implemented a large quantity of timers should be built, and then a sample from this quantity should be built into fuzes and tested. If any further testing of the timer redesign is performed, this testing should be performed with the redesigned escape wheel and lever.

APPENDIX

DRAWINGS

NOTES:
1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL: STRIP, 440 A DWG 9236490.
3 - HEAT TREAT TO KNOOP 576 MIN REF APPROX EQUAL TO RC 52.
4 - 125/ ALL OVER, EXCEPT AS SHOWN.
5 - PERMITTED AROUND ENTIRE INTERNAL AND EXTERNAL PROFILE.
6 - PART MAY BE CONCAVE OR CONVEX WITHIN .002.

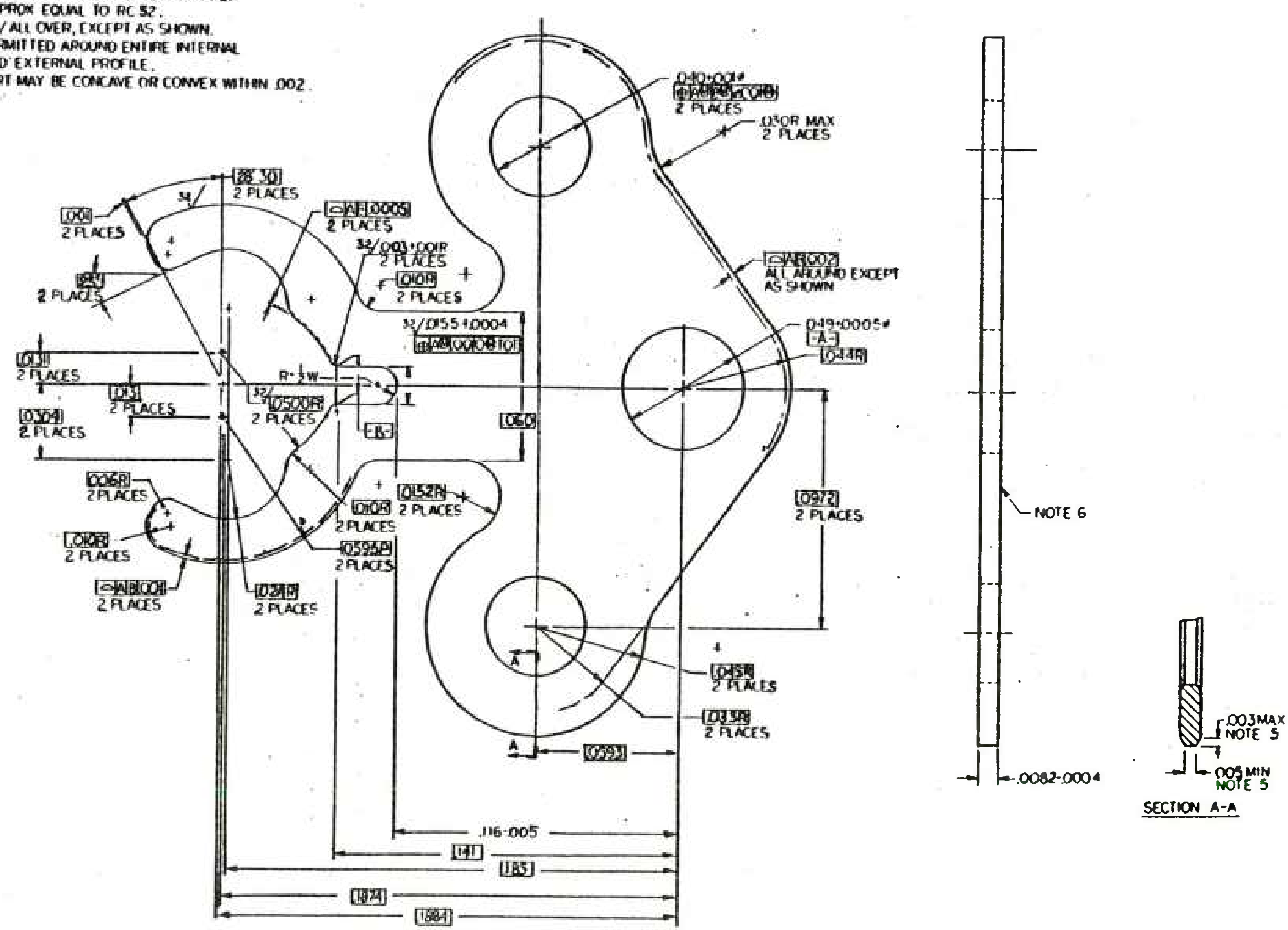

Figure A-1. Timer lever for M577 fuze (part 11786107)

NOTES:
1 — SPEC MIL-A-2550 APPLIES.
2 — MATERIAL COPPER-BERYLLIUM ALLOY PLATE, SHEET, STRIP AND ROLLED BAR, TEMPER A, ASTM B194.
3 — 17 TEETH EQUALLY SPACED.
4 — 125/ ALL OVER, EXCEPT AS NOTED.
5 — PART MAY BE CONCAVE OR CONVEX WITHIN .002.

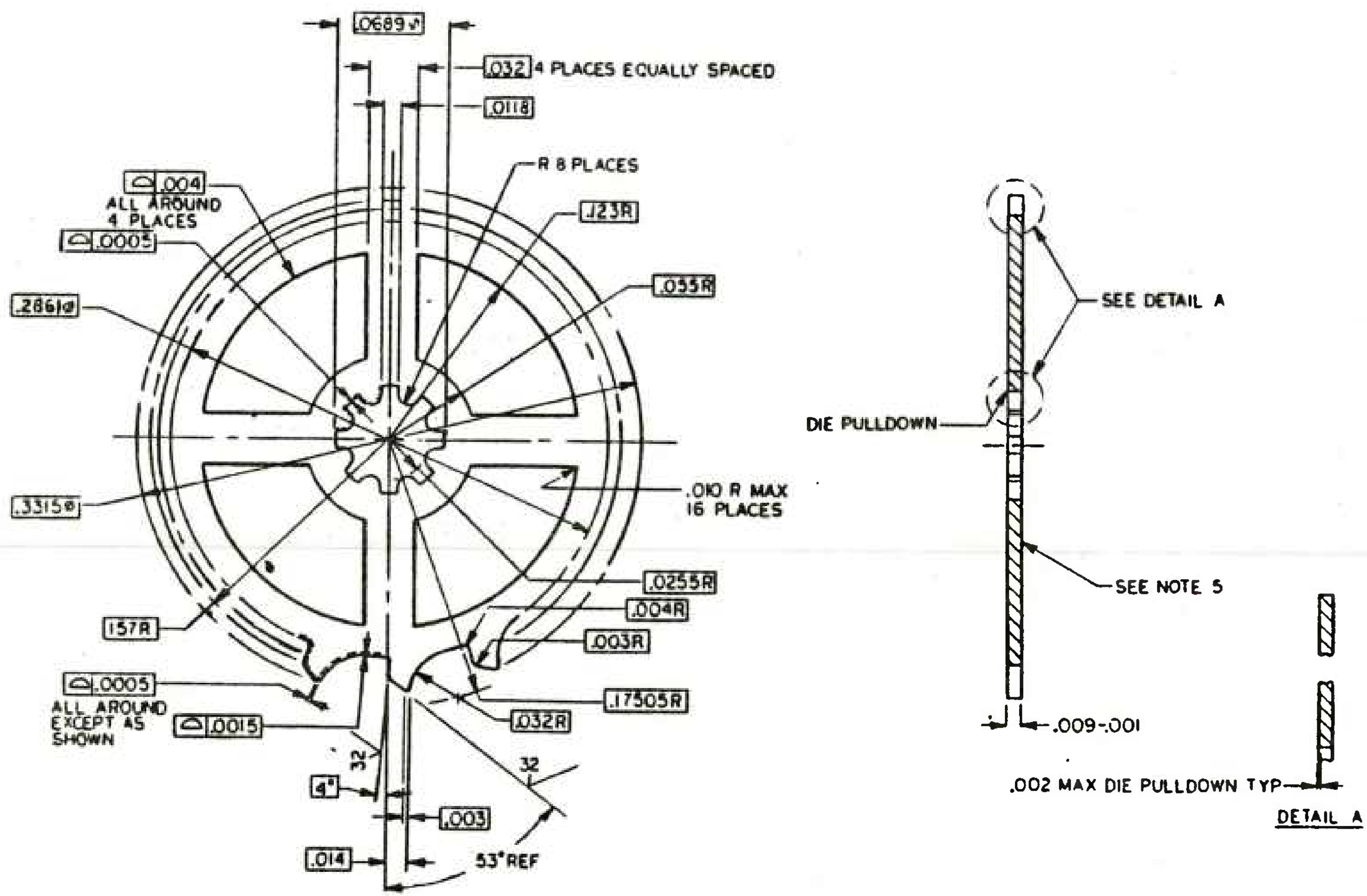

Figure A-2. Timer escape wheel for the M577 fuze (part 11786108)

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